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The adhesive properties of viscoelastic liquid films

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The Adhesive Properties of Viscoelastic Liquid Films

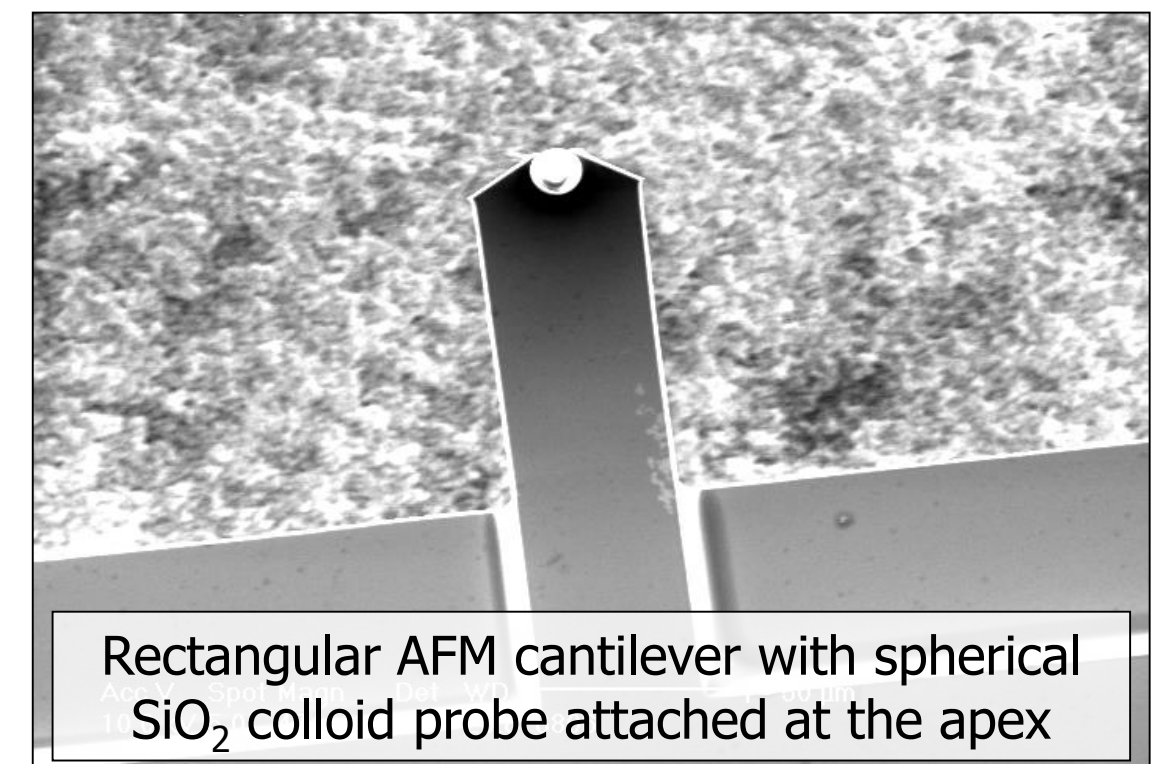
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1. Introduction

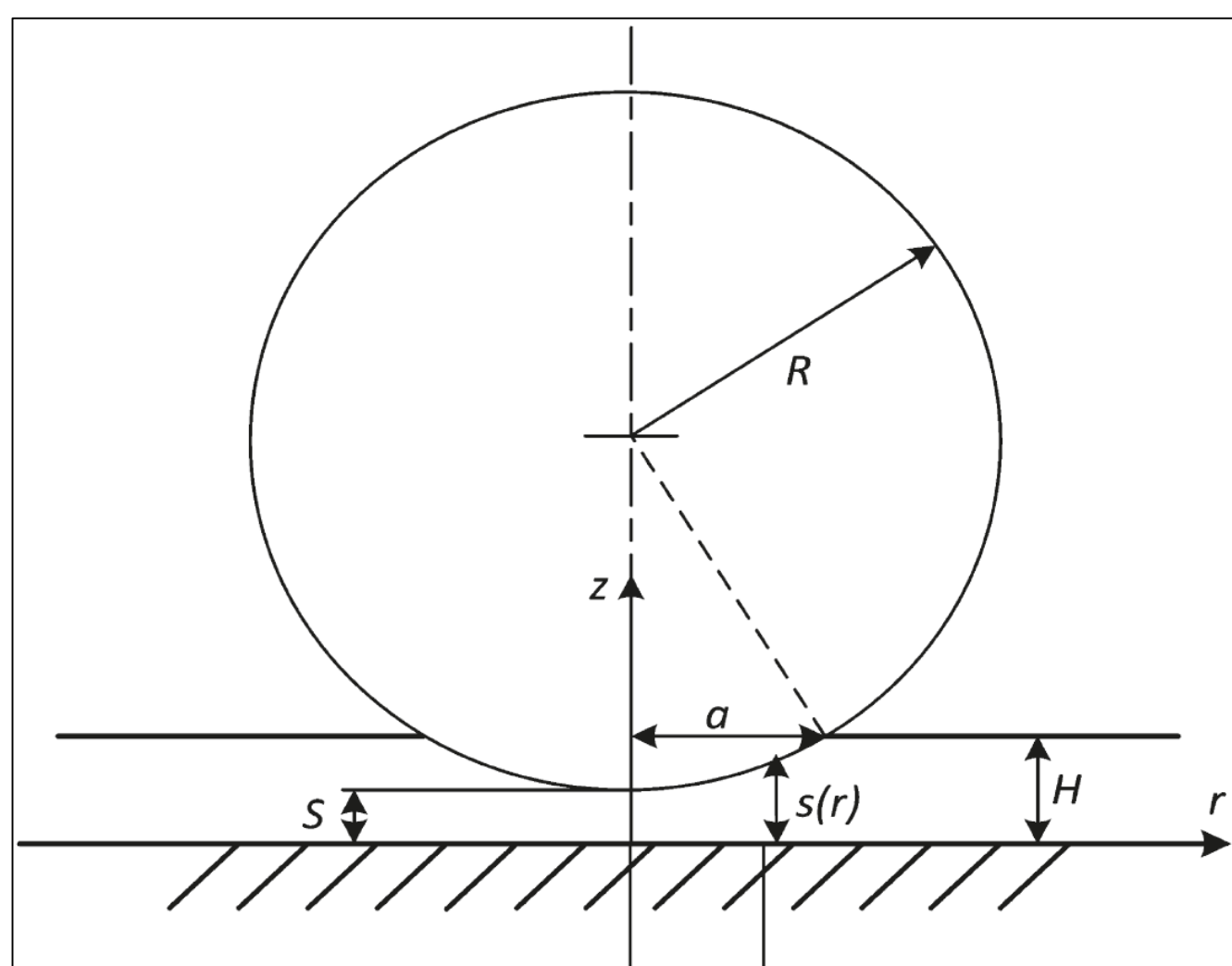
The adhesion of poly(dimethylsiloxane) (PDMS) liquid films was measured using colloid probe atomic force microscopy (AFM). Molecular weights in the range 7 - 250 kg/mol were used, which corresponded to Newtonian and non-Newtonian liquids with zero-shear rate viscosities in the range 10^{-1} - 10^3 Pa.s.

Fixed end retraction velocities in the range 10^2 - 10^5 nm/s were used, with the colloid probe approached to within 10 nm of the substrate onto which the PDMS film was spin coated. Film thicknesses in the range 0.2 - 2.0 μm were investigated. The SiO_2 colloid probes exhibited radii in the range 2.5 - 6.0 μm .



Rectangular AFM cantilever with spherical SiO_2 colloid probe attached at the apex

2. Theory and Experimental



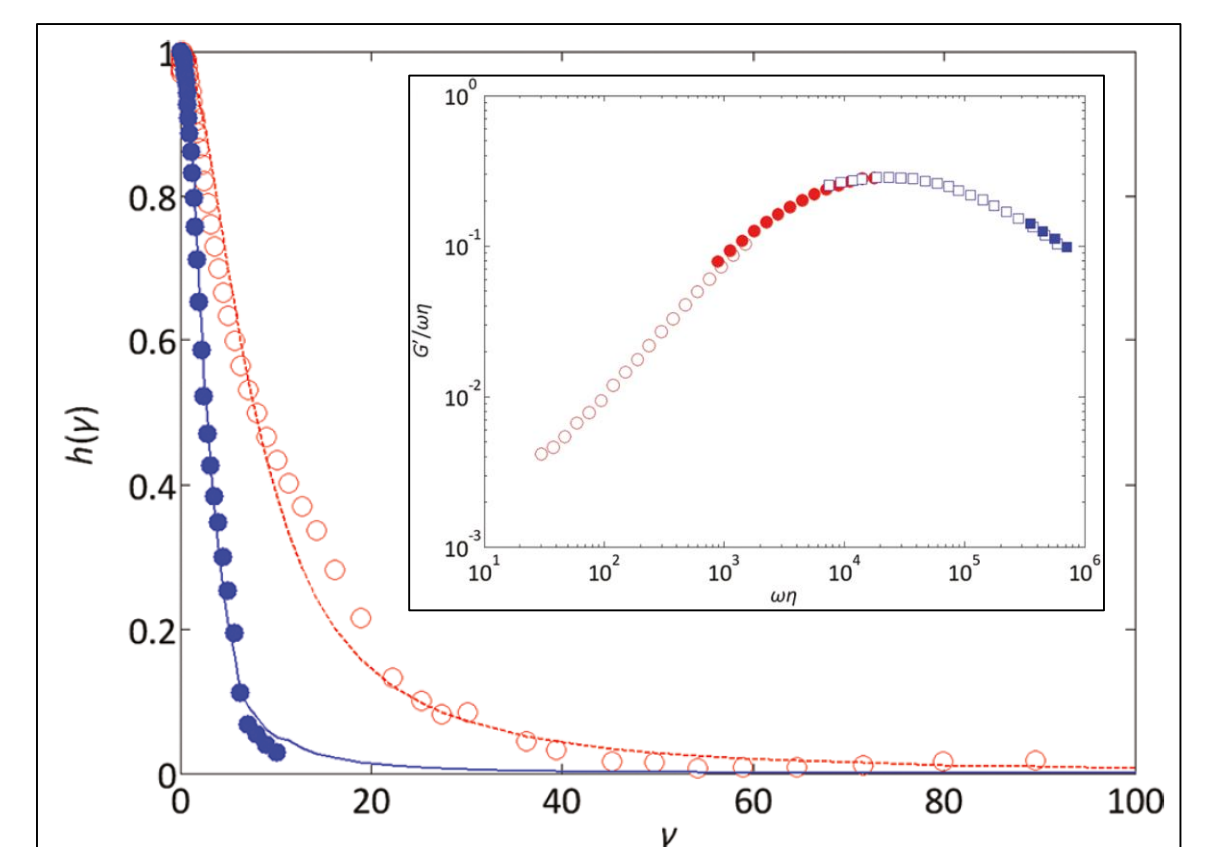
A model was derived for calculating the time-dependent adhesive force during the separation of a liquid junction; this comprised:

- the cantilever, which is the compliant load measuring element;
- a colloid probe at the cantilever free end, which contacts the sample;
- physical properties of the PDMS liquid film, including surface tension, film thickness, and contact radius;
- rheological properties of the PDMS liquid, including non-linear viscoelasticity, described using a generalised Maxwell model.

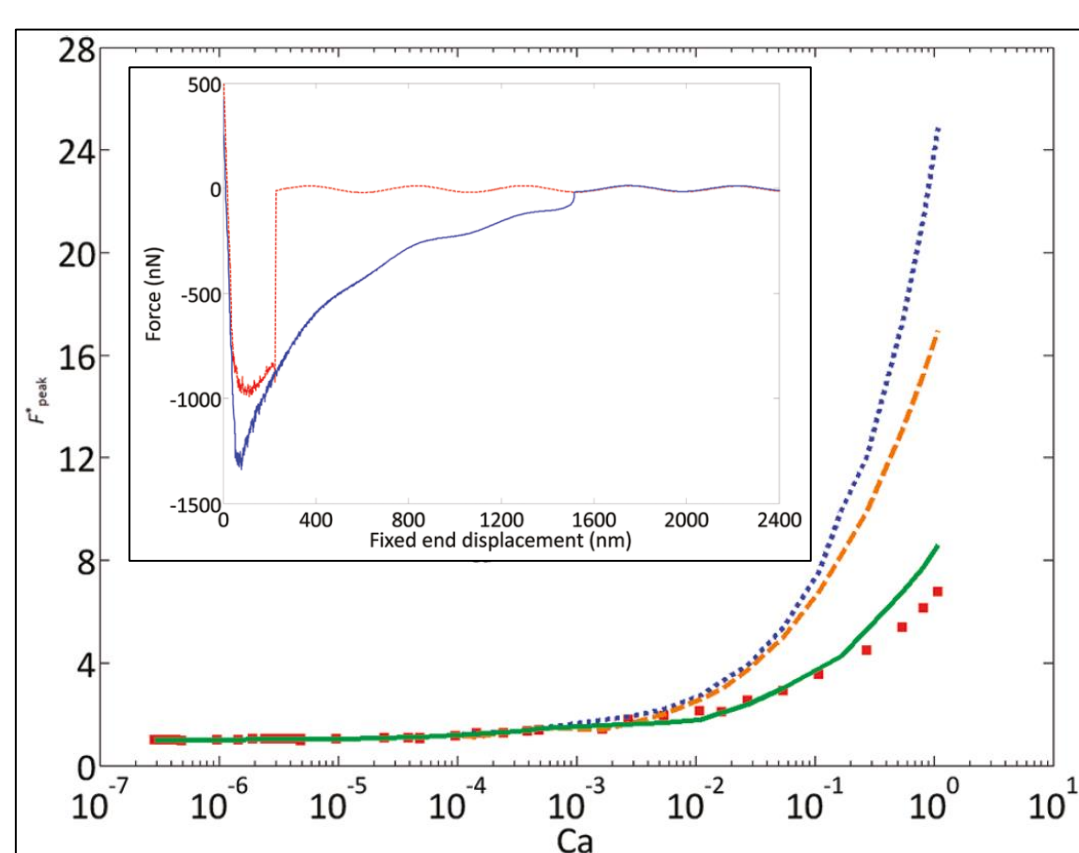
The capillary number, Ca , was used to allow meaningful comparison of the wide range of viscosities and velocities investigated.

3. Results: Rheometry

- Critical entanglement molecular weight for PDMS liquids is 34 kg/mol.
- Non-Newtonian PDMS liquids required between 1-4 elements for successful fitting to the generalised Maxwell model, depending on molecular weight.
- Master curves for storage and loss modulus permitted extrapolation for frequencies which were not experimentally accessible.
- Measurable strain dependence for PDMS liquids with molecular weights in excess of 60 kg/mol.
- Two-parameter damping function used for fitting strain dependence data.



4. Results: Atomic Force Microscopy



- Incorporating the rheological properties of PDMS liquids was crucial to constructing an accurate model, including capillary and viscous forces.
- Beam mechanics, including inertia and acceleration, also present in the model.
- Peak force dominated by capillary contribution for $Ca < 10^{-3}$.
- For $Ca > 10^{-3}$, peak force increases with increasing Ca due to viscous contribution.
- Good agreement between experimental data and simulation for $10^{-7} < Ca < 10^{-1}$.
- Contribution from stress overshoot negligibly small due to low velocities of AFM.

Acknowledgements

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This poster is a summary of the paper published in Langmuir:

"Application of colloid probe atomic force microscopy to the adhesion of thin films of viscous and viscoelastic silicone fluids".

Langmuir **2011**, 27, 11489-11500; DOI: 10.1021/la202060f

The paper can be obtained by scanning the adjacent QR code.

